Petrology and Geochemistry of Pegmatites in Parts of Bihar Mica Belt, Bihar.

BY

ANWAR RAIS

A THESIS
SUBMITTED TO
ALIGARH MUSLIM UNIVERSITY
ALIGARH (U. P.) INDIA
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

Master of Philosophy

DEPARTMENT OF GEOLOGY

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Aligarh 14.9.1978

This is to certify that Mr. Anwar Rais has completed his research work, presented in this thesis, under my supervision for the degree of Master of Philosophy of the Aligarh Muslim University, Aligarh. This work is original and has not been submitted for any other degree at this or any other university.

Syed M. Zainuddin

(Syed M. Zainuddin)

ABSTRACT

The method of prospecting and exploration of economic minerals, such as muscovite, beryl columbite-tantalite, lithium and uranium minerals, in the pegmatites generally adopted in Bihar Mica Belt is unscientific. There has been no criteria or guide, which can help the miners or prospectors in locating the various economic minerals bearing pegmatites. Detailed geochemical studies of the pegmatites of Bihar Mica Belt have also not been done.

The present study was conducted to evolve a geochemical criteria or guide which could help in locating the new economic minerals bearing pegmatites. For a comparative study, the pegmatites were classified on the basis of economic minerals present or are reported to have been produced in the past. Those pegmatites which do not contain any economic mineral in profitably exploitable amount are grouped as barren pegmatites. Major and trace element concentrations were determined in Potash-feldspars of the various types of pegmatites. K_2O, Na_2O, K_2O versus CaO plots show distinct fields for different types of pegmatites. Data of trace elements concentrations is not significant and does not reveal any difference in the various types of pegmatites.

Triclinicity ($\triangle$) values also do not show any difference in range for a particular type of pegmatite; all K-feldspars

studied are "maximum microcline", suggesting the temperature of crystallisation of all types of pegmatites probably below 400°C. The amount of Na_2O + CaO in K-feldspars of the various types shows significant variation; the average value in the barren pegmatites is 3.05, in muscovite bearing pegmatites 2.98 and in beryl, columbite-tentalite bearing pegmatites 2.83.

As Na and Ca are incorporated into the structures of K-feldspars at higher temperature, the amount of Na + Ca incorporated in K-feldspars may be an indicator of the temperature of crystallisation. Barren pegmatites having higher values of Na_2O + CaO, probably crystallized at higher temperature. Beryl, columbite tentalite and uranium minerals bearing pegmatites crystallised at lower temperatures. Muscovite bearing pegmatites crystallised at a temperature less than the barren pegmatites and more than beryl, columbite-tentalite and uranium minerals bearing pegmatites.

The concentration of Na + Ca in K-feldspars may be used as a guide in locating the economic mineral-bearing pegmatites and deciphering them from the barren pegmatites.

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ANWAR RAIS

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CHAPTER I

INTRODUCTION

The Bihar Mica Belt, covering an area of about 6,400 sq.km. (160 km. in length and 40 km. in width), extends from Gaya in the west to Bhagalpur in the east, passing through Hazaribagh, Nawadah, Giridih and Monghyr districts of Bihar State. The belt lies between latitudes 24°25' and 24°45', longitudes 85°25' and 86°30' (Figure 1).

Bihar Mica Belt produces 65% of the total Indian output and contributes about 80% of the world's requirements of sheet mica, (Murthy, 1964). The greatest production from the belt in the past has been within the Kodarma Reserve Forest occupying an area of 147.44 sq.km towards north of Kodarma town (Dunn, 1962). Even today, the Kodarma Reserve Forest is the main area for production of muscovite, beryl, and columbite-tantalite, also for lithium and uranium bearing minerals. Kodarma is situated in the western part of the belt on Ranchi-Patna road, about 75 km east of Gaya on Grand Chord Railway line. Kodarma town is 6 km north of Kodarma Railway station. In the eastern part of the belt, the main area for production of economic minerals in pegmatites is around Jhajha and Chakai (in Monghyr district), 110 km from Patna on main railway line. Jhajha-Chakai zone, in the east, is connected to the Kodarma Reserve Forest in west by metalled road via Jamua and Domchanch.

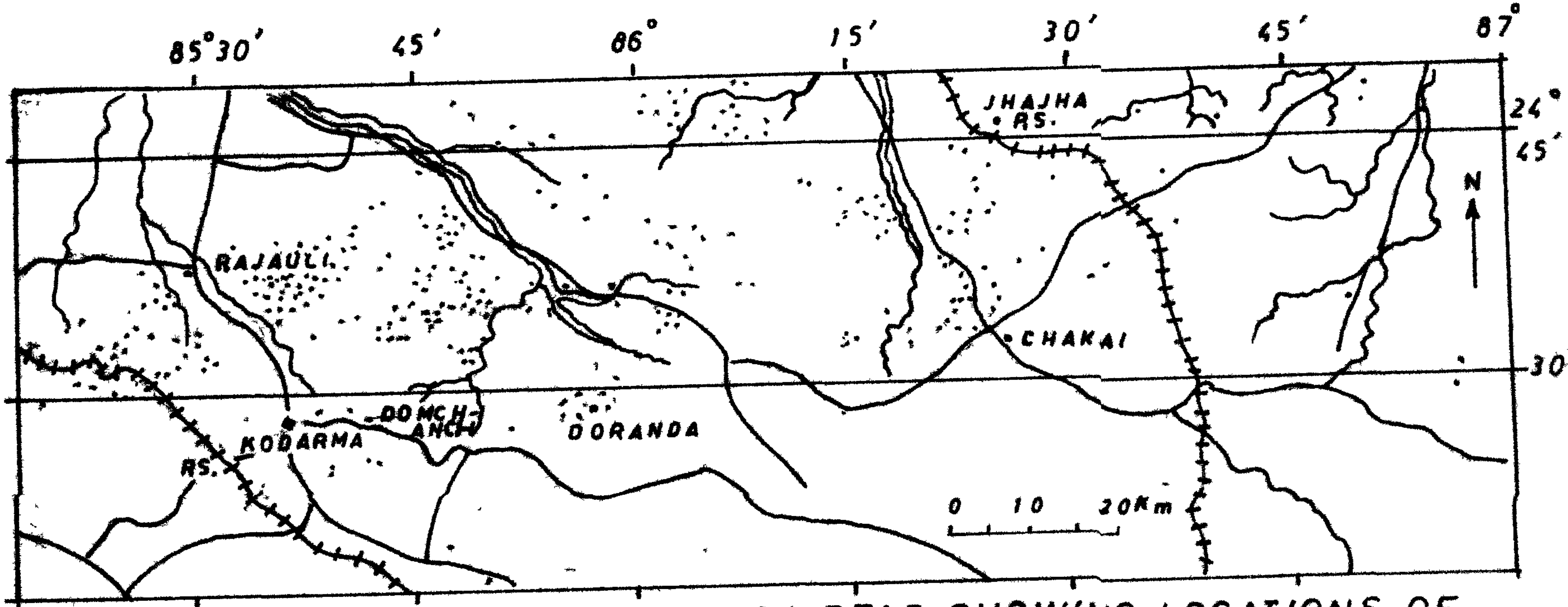

FIG. 1 MAP OF THE BIHAR MICA BELT SHOWING LOCATIONS OF SOME IMPORTANT PEGMATITES.

·Location of Pegmatites

Vegetation is dense and soil is thick in Kodarma Reserve Forest; the jungle consists mainly of Sal trees, bushes and shrubs. Bamboo jungles also occur in some parts but as we move to the east towards Jhajha-Chakai zone, thick jungle starts to diminish and only barren ridges with scattered bushes and shrubs are met.

Ridges range in elevation from few feet to thousands of feet in Bihar Mica Belt. The highest topographical feature is situated in the west of Kodarma Reserve Forest near Rajauli, locally known as Debaur ridge having an elevation of 2,220 feet and is capped by granitic rocks. The ridges formed by pegmatites are generally low in elevation. Topography is controlled mainly by lithology; most of the ridges are capped by quartz cores of pegmatites and granitic rocks, and the valleys by schistose rocks.

The drainage pattern is dendritic which is controlled by the lithology. Many rivers and streams traverse the belt. Tilaiya nadi in the far western portion of the belt, Dhanarji nadi in the middle western portion, Sakri river in central and Barnar nadi in the east flow through the Mica Belt more or less in the north western direction. Many other small streams and tributaries which join the main rivers also flow in the area.

Climate of the area during cold season is dry and cold but in the end of March and during April, May, and June, the temperature is high, generally exceeding 110°F, and therefore, field work becomes difficult during this time of the year.

Nature and Object Study

Extensive prospecting operations have been carried out in Bihar Mica Belt; almost all the pegmatites that have surfaced out- crops have been prospected, atleast superficially. So far, the method of prospecting for muscovite is unscientific and is done mainly through long experience by illiterate people who have been doing this job for generations. The miners or prospectors spend a lot of money in random digging and trenching in search of economic minerals in pegmatites without having any knowledge of any guide or criteria for the location of such minerals. Much has been published on the general nature of the pegmatites but no detailed study on the control, localisation and distribution of various minerals has been done. Majority of the previous workers have studied only the mineralogy and mode of emplacement of the pegmatites, whether they were structurally or lithologically controlled at the time of their emplacement.

No attempt has been made to evaluate geochemistry and the composition of the pegmatites in any great detail by systematically sampling the pegmatites and analyzing them chemically. Studies to evaluate the elemental associations have also not been carried out on a significant scale. Due to the lack of data, certain broad generalisation based on mineral composition may only be made about the bulk composition of the pegmatites.

The present study was aimed to determine the criteria which can be used as guide for locating major and accessory minerals of economic importance such as beryl, columbite-tantalite, lithium and uranium minerals, in the pegmatites.

Sampling:

The nature of the present study is mainly geochemical; samples of different pegmatites, known to be economic mineral bearing, were collected for chemical analyses. Samples were also taken from barren pegmatites to study the difference in their chemistry and the various economic mineral bearing pegmatites. Since most of the economic minerals bearing pegmatites are zoned, samples from such pegmatites were collected from each zone for comparative study. Pegmatites of various types which were studied and from which samples were collected are shown in Figure 2.

natites Studied

PREVIOUS WORK

The word pegmatite was first used in print by Brongniert (1813) who described the term pegmatite as synonym to "graphic granite"; a granite having graphic intergrowth of quartz and feldspars. Later in the same sense it was used by d'Abbuissen (1819) and Haüy (1822). But after 1850 the term pegmatite was used with two meanings; first for graphic granite, and second for those coarse grained light coloured differentiation products which are end members of granitic and other intrusions. Haidinger (1845) was first to use the pegmatite world for coarse grained feldspar rich granites, and Dellesse (1849) used the term for very large grained rock consisting of orthoclase, quartz and silvery mica, which occur commonly in the form of dikes, small stocks and nests in other rocks.

A brief report on the geology and mode of occurrence of pegmatites of Bihar Mica Belt was published by Mallet (1874). First systematic and detailed mapping of a large portion of the belt was done by Iyer during 1939-1944. Northeastern part of the belt has been remapped by Vemban (1950), Mahadevan (1957), Alwar (1958) and Thiagrajan (1960-1961). Sharma (1958) has studied the feldspars in the Mica pegmatites and found atleast two distinct phases of feldspar formations in the pegmatites; the first potasic, and the second, sodic. Detailed petrographic features of the rocks of the Bihar Mica Belt were later described by Sharma (1940). Deformational features in quartz, feldspars and beryl in the pegmatites have been given by Sen and Saha (1961).

Radioactive age determinations of pegmatites have been carried out by Holmes (1950 a) and Mahadevan and Aswathnarayana (1955) on the specimens of monazite from Pichhli pegmatite near Singer village in Gaya district. They have reported an age of 955± 40 my. of pegmatites in Bihar Mica Belt. The fission track ages of four cogenetic minerals, garnet, muscovite, biotite and apatite, collected from different pegmatites of Bihar Mica Belt are found to be 830 my, 760 my, 595 my and 590 my respectively. The discordance has been interpreted in terms of tectonic and cooling history (Lal et al. 1976).

Zoning in pegmatites was first recognised by Tipper (1916) but the published account of the zoning in pegmatites is that of Roy, Sharma, and Chattopadhyaya (1939); they have shown diagramatically a central quartz body with marginal muscovite-plagioclase zone. The mica is concentrated either on the margins of quartz core or in the border zone of pegmatite. Systematic study of zonal features of individual pegmatite was initiated by Vemban and Mahadevan (1951); They have deciphered a number of zones characterized by mineralogical and petrographic divergence.

First exhaustive account of the origin of Mica pegmatites was published by Holland (1902) who concluded that the Mica pegmatites were formed from "Hydatopyrogenetic" magmas which themselves resulted as residual portions of granitic magmas. The high fluidity of the magma was ascribed to high content of water and fluorine. Vredenberg (1910) postulates that an anhydrous solvent was produced at great depth with high fluidity due to its fluorine content. This solvent assumed granitic composition by assimilating granitic material during its ascent.

Biswas (1929) considered that the Mica pegmatites have formed from a residual magma which assimilated large amounts of schists at depth and precipitated muscovite after its final emplacement. Dunn (1942) suggested that pegmatites were formed from solutions of magmatic origin, originally potassic and siliceous in composition and containing volatile constituents such as H_2O, O, Li, B, F, with rare Be and oxides. Such solutions change their composition during their migration and "deposition of their constituents" in the mica diabrochites. Passing from granite into mica schist and diabrochites, the solutions immediately change in composition. The contrast in the mineral composition of the veins is sharply marked within a few yards; pink potash feldspars may still be present but soda feldspars at once become dominant in the mica schist. Roy, Sharma and Chattopadhyaya (1939) recognized two distinct types of pegmatites, the plagioclase pegmatite and microline pegmatite; the latter is older in age. They opined that the crystallization of muscovite is due to the action of potash and alumina solutions released during the desilicification of microcline somewhere at the lower and deeper portions of the simple pegmatites. A similar view has been expressed by Rode (1947). Fox (1930a and b) accounted for the concentration of muscovite by the recrystallization of mica schist under the influence of hot waters which probably derived its heat and some constituents from the adjacent granitic intrusions.

All workers (except Roy, Sharma, Chattopadhyaya, 1939) now recognise the role of solutions and volatiles and contribution from the country rock in the formation of Mica pegmatites. The views only differ on the extent of the contribution of country rocks and source of highly aqueous solutions.

In the recent past, much attention was paid to the petrogenetic studies on feldspars and micas occuring in pegmatites. On the basis of occurrence, composition and optical properties, petrogenesis of feldspars in pegmatites was discussed by Anderson (1928). The petrogenetic studies on feldspars took a new path after 1930 when intense thermal, Xray, spectrographic and phase-equilibrium studies were used in solving fundamental problems. Radioactive minerals, particularly uranium bearing minerals have received much attention because of their variety of occurrence, complex composition and usefulness as atomic fuel.

Classification of pegmatites:

Johnstone (1945) classified the pegmatites on the basis of texture; those having uniform texture and mineralogy throughout the body were called as homogeneous (unzoned), and those showing marked variations in texture and mineralogy from border to core of the pegmatite body were termed as heterogeneous pegmatites. It is a nongenetic and simple classification and is useful in distinguishing the pegmatites. Cameron et al. (1949) classified the pegmatites into fracture fillings which are usually tabular, replacement bodies which have been formed by the replacement of pre-existing pegmatites, and zoned units which may be symmetrical or asymmetrical. Zones have been further divided into border zones, wall zones, intermediate zones and cores with reference to their position in space.

Gevers (1936) has classified the pegmatites, on the basis of their relationship with supposedly parental granitic bodies, into interior, Marginal, and Exterior pegmatites, occuring within the granite itself, at contact of granite and invaded rock, and outside the granite body respectively. These terms could be useful and acceptable for describing the spatial relationship of pegmatite bodies. Pegmatites have also been classified into simple and complex pegmatites by Schaller (1933) and Gevers (1936). The simple pegmatites are those which consists essentially of microcline and quartz. Complex pegmatites are those which, in addition to microcline and quartz , contain an abundance of one or more of such minerals as albite, beryl, topaz, cassiterite, micas, tourmaline, garnet, lithium minerals, rare-earth and minerals, columbates and tantalates, the phosphates and others. According to Schaller (1933), complex pegmatites originally were simple pegmatites which have had their mineral contents changed in whole or in part by the replacement action of the later hydrothermal solutions. The solutions removed much of the microcline and in part also the original quartz and substituted in their place, the other minerals mentioned above, together with new quartz and new microcline. Such pegmatites have been termed as "Polyphasic" pegmatites by Gevers (1936).

CHAPTER II

GEOLOGY OF THE AREA

The pegmatites commonly occur in mica schist which cover an area of about 67 percent of the Bihar Mica Belt; the schists show varying gradations from muscovite-biotite-schist to types rich in quartz, fibrolite (and sillimanite) and garnet. The most dominant type, however, is the fibrolite-muscovite-biotite schist. The schists contain upto 15 percent plagioclase feldspars (An_{28} to An_{33}) which occur as anhedral grains. The foliation in schistose rocks strikes almost ENE- WSW and is parallel to the original bedding, except along noses of folds. Foliation is poorly developed where bedding is well preserved and along the noses of folds. The schistose rocks are well lineated, mainly due to the elongation of minerals, crenulations in micas and rodding in quartz; the lineation plunges 30° to 60°, the direction of plunge vary from ENE to even ESE.

Folding in metasedimentary rocks have controlled the main structural trends in Bihar Mica Belt. The strike of the fold axis varies from NNE-SSW to ENE-WSW, as well as to ESE-WNW. The pattern of folding is of the broad open type and not the tight folding.

The granitic rocks, at places forming dome shaped hills, cover about 33 percent of the total area of the Bihar Mica Belt. Due to their characteristic physiographic expression, they are called "Dome gneisses" (Holland, 1902). The important granitic bodies in the area are, the Debaur Mass, the Singrikhi-Barachuan Mass, the Taraghatti, Kodarma-Domchanch Mass, the Mahuapanr Mass, the Dhuba Mass, the Baghrujot-Bhatti-Dhab Mass, and the Jamdar Mass, besides other small bodies. They may be classified on the basis of structural features into two broad types. Strongly to mildly foliated and lineated gneisses, mostly non-porphyritic occuring as phacolithic sheets along noses and limbs of folds constitute the first type. This type of granitic rocks are most extensive; the Singrikhi-Barachuan mass, the Taraghatti-Kodarma-Domchanch mass, the Baghrujot-Bhatti-Dhab Mass, and Jamdar mass belong to this category. Second type is massive equigranular rock forming sub-elliptical boss like bodies. They are foliated along their margins with country rocks. The Dhuba Mass and the Mahuatnr Mass belong to this type of granitic rocks.

Petrographically, there is not much difference in the above mentioned types of granite. Both the types consist of microcline, perthite, plagioclase (oligoclase-andesine), quartz, biotite, and hornblende in varying proportions. llanite, epidote, fluorite, apatite, zircon, garnet and iron ore occur as accessory minerals. Microcline and plagio-clase feldspars show evidence of shearing and later recrystallisation. Granite bodies are of two generations, the foliated type are syntectonic and non-foliated massive types were emplaced subsequently when shearing stresses or forces were over. Both types of granitic rocks have sharp contacts with country rocks.

The following tentative geological succession for Bihar Mica Belt has been proposed by Sugavanam and Sharma (1965).

Recent	- Alluviam
Lower Gondwanas	- Talchir Sandstone and boulder bed
Unconformity	
Archaeans	- Pegmatites and Quartz veins. Basic intrusives - delerite and amphibolite, granite gneisse.
	Pink Porphyritic gneissic granite, Horblende schist and amphibolite, Quartz-muscovite schist, quartz-sillimanite-muscovite schist and Micaceous quartzite.

CHAPTER III

NATURE OF PEGMATITES IN BIHAR MICA BELT

The pegmatites of the Bihar Mica Belt are emplaced along joints, tension fractures, foliation planes, bedding planes, limbs and noses of folds etc. Commonly the pegmatites are concordant to the bedding planes or foliations of the country rocks, but discordant pegmatites are also not rare.

Shape and size of the pegmatites of the belt are variable, generally they form long narrow bodies thinning out at both ends and tapering out at depth also. The pegmatites range in length from 15 metre to 700 meters. Among the pegmatites studied, the Bhanekhap Mica pegmatite, approximately 700 meters in length on surface, is supposed to be the longest pegmatite. Width of the pegmatite bodies vary from one meter (Aglagwa Mica Pegmatite) to 150 meters (Tandhaiya Mica pegmatite). Some of the veins are lenticular in shape having a maximum thickness at the central portions. In others, the thickness varies from place to place due to repeated pinching and swelling nature of the vein. In such pegmatites it is difficult to predict whether the vein which has thinned down would widen out if further pursued. Drilling on pegmatites at Doranda and Ghortappe by Atomic Minerals Division has revealed that these pegmatites pinch out at depth. Bhola (1966) has observed that most pegmatites show a tendency to pitch at depth.

Pegmatites may be arcuate, sinuous or oval shaped depending upon the structures and open spaces into which they have been emplaced. Shapes of the pegmatites can not be correctly defined because of their irregular nature and also because they reappear both along strike and dip. They thin down to stringers in many cases and can be traced for long distances. Sometimes, a single pegmatite, due to its habit of pinching and swelling, appears as two or more separate bodies. Because of this nature, often there are more than one mine on the same pegmatite; Sethwa pegmatite, which has Sethwa mica mine, in the northern portion, was previously mined for ruby mica on its southern end, the mine was called Dagdagwa mica mine.

Pegmatites occuring within the granitic rocks are commonly seggregated masses with sharp boundries (Mahadevan and Maithani, 1967). Their grain size vary from a centimeter to a decimeter. Such pegmatites may be zoned or unzones; when zoned, the quartz core of the pegmatite is surrounded by perthite-quartz zone or perthite-albite-muscovite-quartz unit. These pegmatites are mostly barren (lack commercially exploitable concentration of economic minerals) or are columbite-tantalite or uranium minerals-bearing. Presumably, they were emplaced along fractures in the granitic rocks; as for example the Baghparhi pegmatites in north of Doranda. Pegmatites are more common within mica schist in Bihar Mica Belt. Such pegmatites are most important because most of the economic minerals are found within them. They are commonly zoned and consist mainly of quartz and perthitic microcline, also small amounts of plagioclase, muscovite, biotite and tourmaline. Their contact and textural relationship with the country rock suggest a replacement origin (Mahadevan et al. 1967). Pegmatites also occur in micaceous quartzite but such pegmatites are generally devoid of economic minerals.

Zoning in pegmatites form important internal structural features, these units contain maximum economic concentration of muscovite and other minerals. According to Cameron et al. (1949), zones are successive shells, complete or incomplete, which commonly reflect the shape of pegmatite body. These are concentric about an inner most zone or core and the sequence of zones inwards towards the core from any point is same in a typical symmetrical zoned pegmatite. (Figure 3 shows a geological map of a symmetrically zones pegmatite near Doranda). Zoning may be asymmetrical also. In asymmetrical zoning, sequence of zones inwards towards the core is different on either side of the body or a zone may be missing at one side of the pegmatite whereas perfectly developed on the other side.

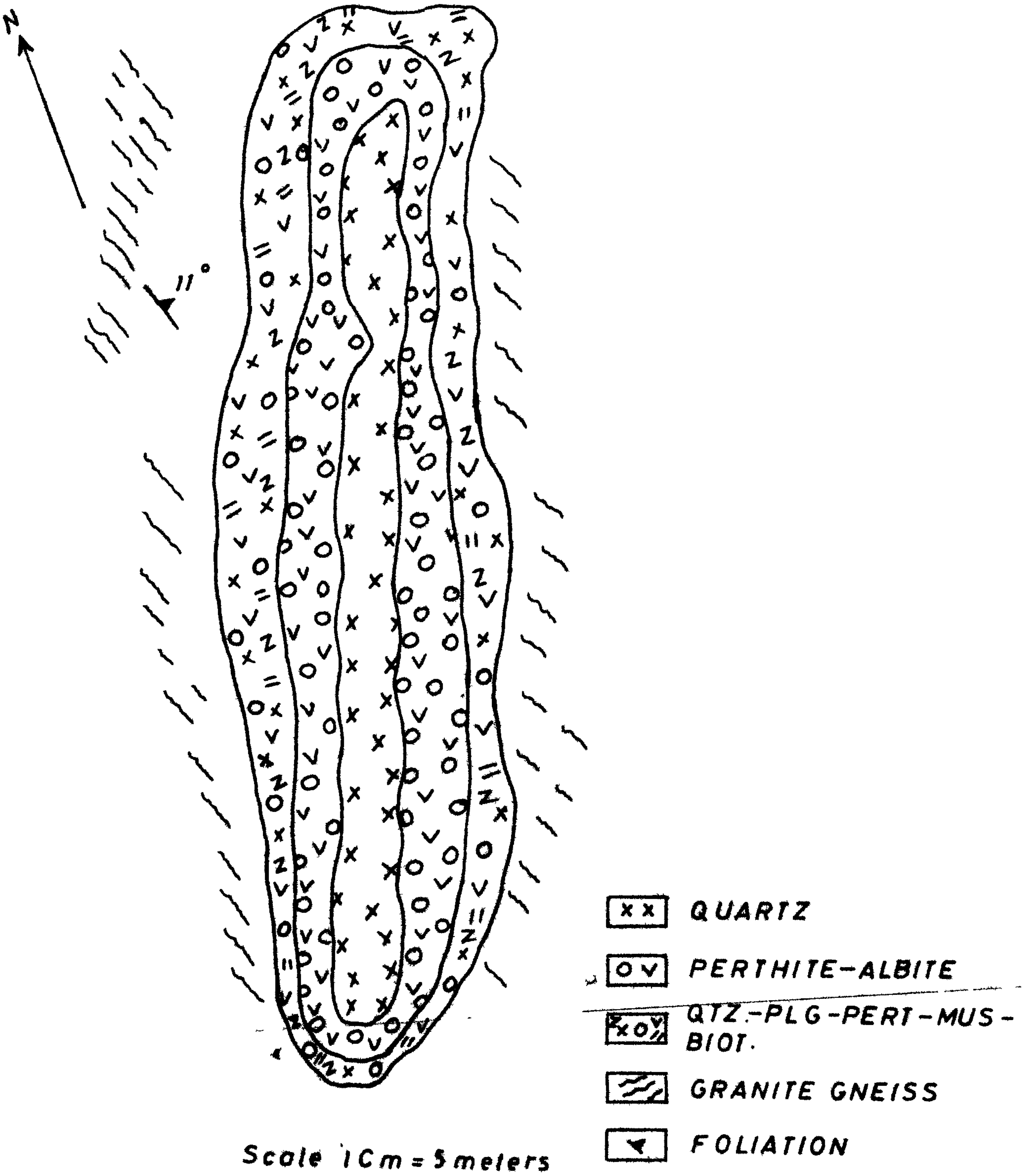

FIG. 3 GEOLOGICAL MAP OF A TYPICAL SYMMETRICAL ZONED PEGMATITE IN NORTH OF DORANDA (CONTACTS MARKED ON THE BASIS OF CORE DRILL DATA OF BHOLA, 1966 AND FIELD OBSERVATIONS)

The pegmatites of the Bihar Mica Belt are generally asymmetrically zoned, either due to absence of a zone or zones at one place and presence of that zone at another place. The symmetrically zoned pegmatites are also found though less common than asymmetrically zoned pegmatites. Unzoned pegmatites are rare in Bihar Mica Belt. Sometimes symmetrically zoned pegmatites may appear as asymmetrical on the surface of the earth due to differential weathering. Such a pegmatite is exposed near Karhara in Monghyr district (Figure 4).

On the basis of mineralogy and texture and also structural position within the pegmatites, zones may be classified as follows (after Cameron et al. 1949).

A. __Border Zones:__ These are outermost zones and are in contact of wall rock. The pegmatite is finer grained as compared to those in the other zones. Such zones are very thin, may range from 15 cm to 1.25 meter.

B. __Wall Zones:__ These are second zones from contact of the pegmatite with the country rocks; generally coarser grained than border zones and commonly grade into intermediate zones. Wall zones are most important among all because muscovite and beryl commonly occur in these zones.

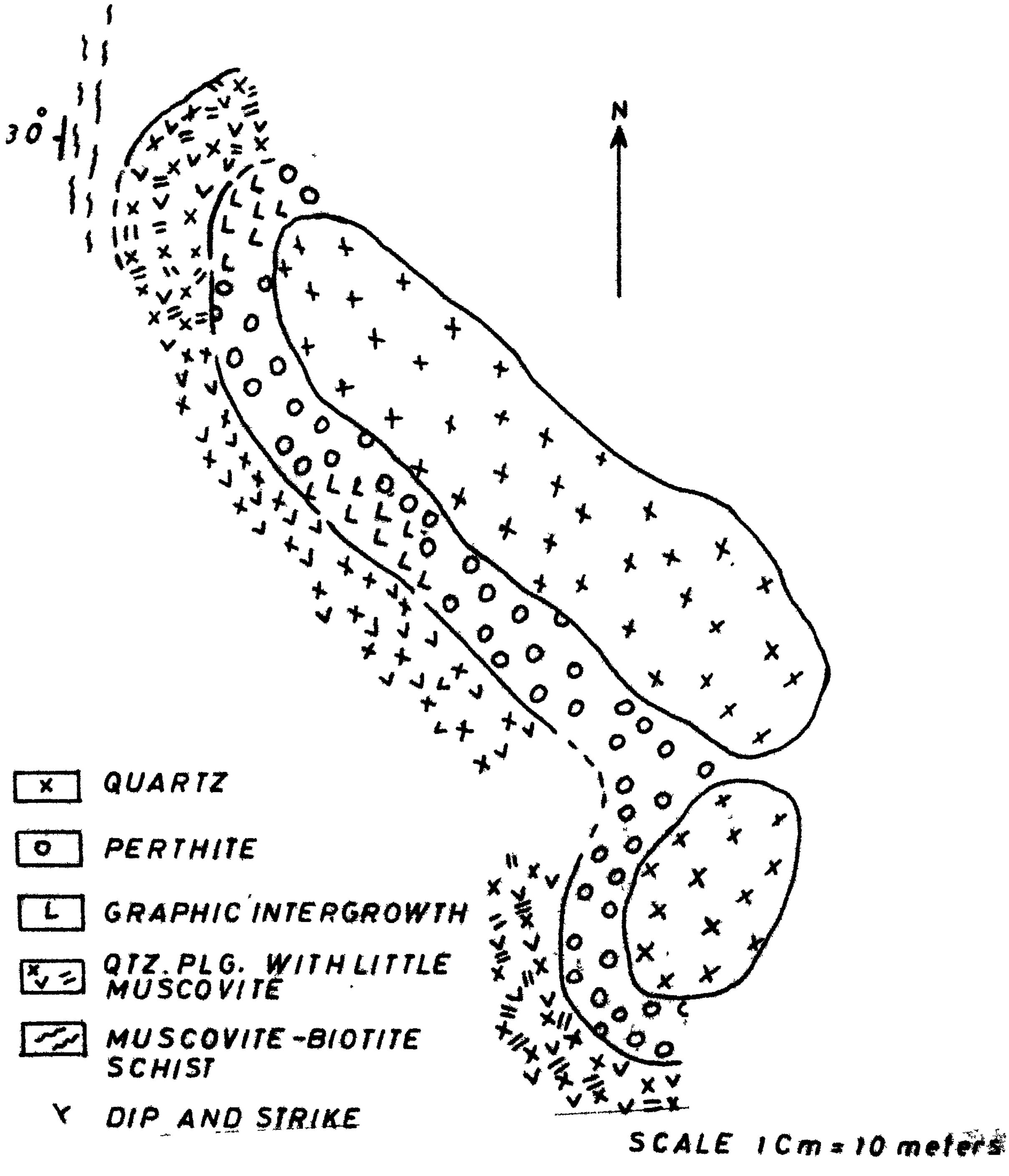

FIG. 4 GEOLOGICAL MAP OF KARHARA PEGMATITE SHOWING A BENT IN SOUTHERN PORTION

C. <u>Intermediate Zones</u>: These zones include all the zones between wall zone and core. They may be very thin and may be represented by a monomineralic thin layer. These zones vary in composition much more than any other zone, and may be representated by only one mineral, may be plagioclase, quartz, muscovite or biotite, or a mixture of two or more of these minerals. The texture of the pegmatite in these zones is coarser than wall zones.

D. <u>Core Zones</u>: These zones are in the centre of symmetrical or asymmetrical pegmatite body and are mainly composed of quartz. The size of the core depends upon the thickness of other zones of that pegmatite. Discontinuous cores are represented by a series of pods or lenses, centrally located in pegmatites. The cores are very coarse in grain size and may contain perthite and plagioclase in some amount essentially with quartz.

Pegmatites have poor topographical expression except when they have quartz cores. The trend of pegmatites on surface is generally marked by the trend of quartz body. The pegmatites of Bihar Mica Belt show varying trends from east-west to almost north-south. Their dip also vary from 40° to 85°, generally the pegmatites are more or less vertical.

The country rocks into which pegmatites were emplaced are generally micacenous schists comprising of muscovite-biotite-quartz-plagioclase ± garnet. Such pegmatites are generally rich in muscovite, beryl, and other minerals. The pegmatites occurring in micaceous quartzite are generally barren. The pegmatites which occur in granites or near granite bodies are also rich in beryl, columbite-tantalite and uranium minerals, but not in muscovite. According to Holland (1902) and Dunn (1942), the mica bearing pegmatites occuring in mica schist, changed their composition on coming in contact with mica schist. Fox (1930) suggested the origin of mica due to digestion and recrystallization of mica schist.

Pegmatites were emplaced either by replacement or by simple intrusion and the mechanism of their emplacement can be inferred from structural relations of pegmatites with the country rocks. The pegmatite which lack in economic minerals in appreciable amounts, generally have discordant relationship with the country rocks, and the pegmatites having economic minerals in profitably exploitable amount are commonly concordant to country rocks. Presence of economic minerals in pegmatites which are concordant and occur in mica schist may suggest an important role played by the host rock in providing sufficient room for their emplacement a large volume and probably addition or interchange of material from the host rock. However, at Tandhaiya, a barren pegmatite (completely devoid of any economic minerals) occurring in mica schist, is exposed adjacent (about 30 meters at the surface and only a few meters apart underground) to a productive mica pegmatite (Figure 5).

The object of present study was to determine a guide for locating economic minerals in pegmatites. As such, in order to study the difference in mineralogy and trace element geochemistry between the various economic minerals bearing pegmatites, the pegmatites of Bihar Mica Belt were classified on the basis of the economic minerals, present in them or were reported to have been mined in the past, into the following types:

1. Muscovite bearing pegmatites,
2. Beryl bearing pegmatites,
3. Columbite-tantalite bearing pegmatites,
4. Lithium minerals bearing pegmatites,
5. Uranium minerals bearing pegmatites, and
6. Barren pegmatites -(pegmatites which lack in economic minerals in profitably exploitable amount are grouped as barren pegmatites).

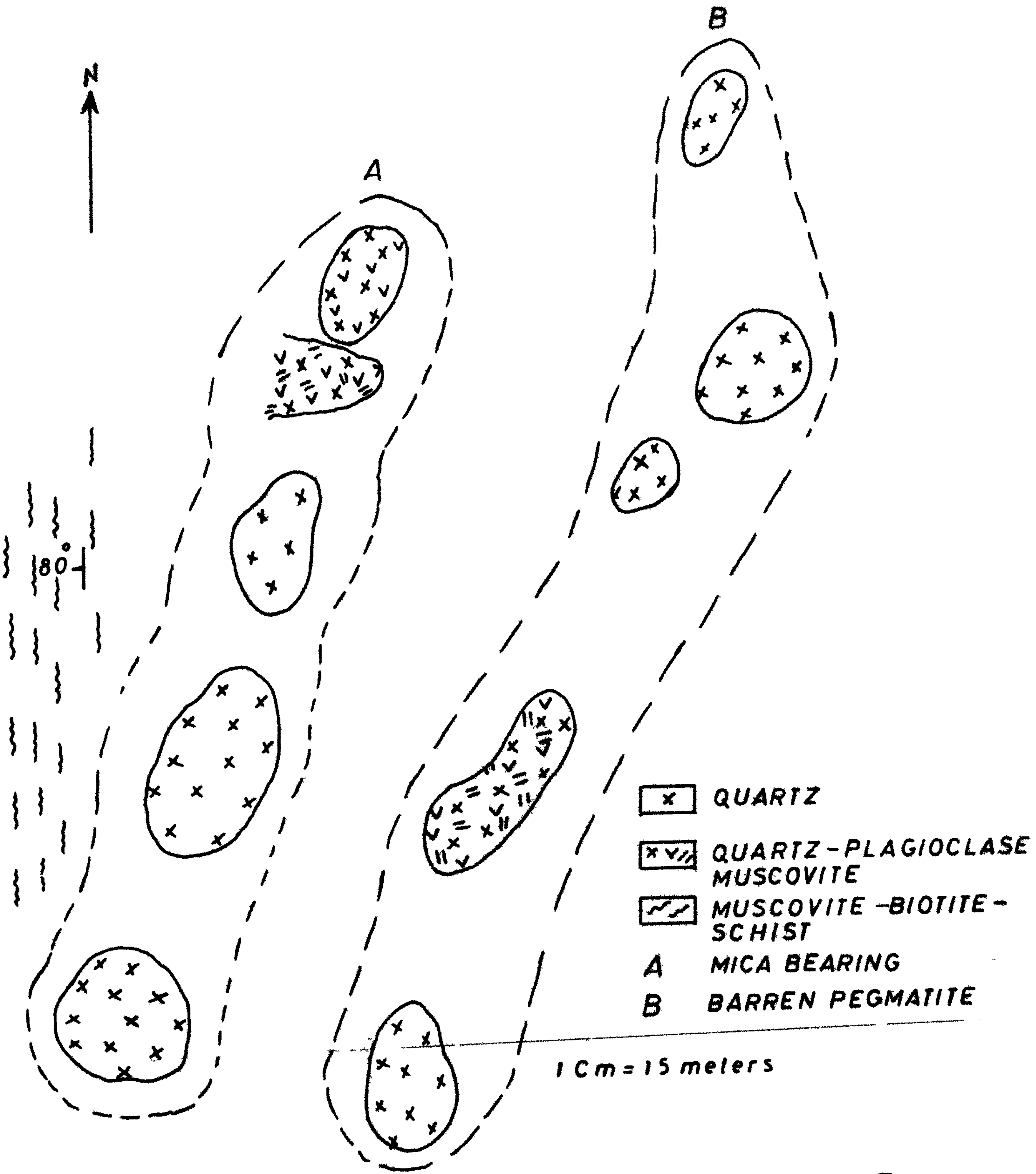

FIG. 5 GEOLOGICAL MAP OF BARREN PEGMATITE ADJACENT TO MICA-BEARING PEGMATITE TANDHAIYA BIHAR.

CHAPTER IV

GEOCHEMISTRY

The petrological and structural data have not always been sufficient and useful for the successful location and exploration of muscovite, beryl, columbite-tantalite, lithium and uranium minerals in pegmatites. Till now, any study to determine a guide for locating economic minerals in pegmatites has not been thoroughly investigated. Nature and behaviour of elements, in a mineral constituting the pegmatite and relative amount of their occurrence, may help us to decipher the different types of pegmatites which in turn may be useful in locating new deposits of muscovite and other economic minerals and also, in classifying different types of pegmatites. A comparative study of the concentration of major and trace elements in a single mineral or in the whole body of the pegmatite of various types may decipher a guide which may help in locating economic minerals bearing pegmatites.

In the pegmatites of Bihar Mica Belt, neither the major element composition nor the study of the trace elements have been carried out in detail by earlier workers. Geochemical study of major and trace elements present in the common minerals of pegmatites may help in understanding the crystallisation history, nature and behaviour of the pegmatite body.

Geochemical studies show a relatively low concentration of Cd, Cr, Co, Ni, Hg, precious metals, selenium, vanadium and relatively high concentration of Sb, As, Bi, Ba, Sr, Rb, Be, Cb, Ta, Cu, Po, Zn, Li, Mo, Wo, rare earths, Scandium, Sulpher, Th, Uranium, Tin, Titanium and Zirconium in pegmatite fluids (Fersman, 1951; and Richard, 1955). The rare elements form easily recognisable minerals in pegmatites as well as are dispersed in structures of common minerals in simple and complex pegmatites.

Richard (1955) quotes Vlassov who suggested a co-relation between the shape and size of pegmatite body and their rare element content in order to understand the nature of pegmatite bodies.

On the basis of petrochemistry and geochemistry of pegmatites, Chakarbarti et al. (1974) classified the pegmatite into deformed and undeformed types. They further subdivided the undeformed pegmatites into muscovite-bearing (with or without beryl and rare earth), beryl, lithium, and radioactive minerals bearing pegmatites. They carried out a study of triclinicity of K-feldspars to determine the temperature of formation, rates of growth, roles of volatiles and intensities of deformation for different types of pegmatites. According to them, the decreasing values of Na_2O and K/Rb ratio and increasing values of triclinicity of K-feldspars, indicating progressively decreasing temperature of crystallization and increasing role of Volatiles, are favourable conditions for the crystallization of mica. The decrease in K/Rb ratio in potash feldspars indicates the successive stages of evolution of pegmatitic magma (Heier, 1962).

Chakarbarti and Saha (1974) analysed sixteen (16) samples of K-feldspars from different types of pegmatites of Bihar Mica Belt to determine their trace elements concentrations. They found marked distinction between the different types of pegmatite; Rb, Cs, Li, Ga, Ba, and Sr are lowest in the deformed type and highest in the rare metal (undeformed) pegmatites. Potash feldspars from muscovite rich pegmatites have high Rb (500-300 ppm), high Cs (50-150 ppm) and high Li (5-45 ppm) concentrations, whereas the rare metal pegmatites show much higher content of Cs and Li in K-feldspars. The Pb content is highest in the deformed pegmatites and progressively decreases in the undeformed type (muscovite and rare metal pegmatites).

Similarly, on the basis of the analyses of twenty one (21) samples of plagioclase from pegmatites, Chakarbarti et al. (1974) have shown that Ga is highest in rare metal pegmatites (50-85 ppm) and lowest in deformed pegmatites. Cu is highest in muscovite bearing pegmatites whereas Pb is highest in deformed pegmatites, decreasing progressively in undeformed muscovite bearing pegmatite and rare metal pegmatites.

Since representative sample of the whole body can not be easily obtained due to the zoning in pegmatites and the extremely large grain size of the constituent minerals, samples of individual minderal from the various zones of the different types of pegmatites were collected. Potash feldspars from perthite zone (intermediate zone of Cameron et al. 1949), adjacent to quartz core, from each type of pegmatites were analysed for comparative study of major and trace elements concentrations.

A part of the rock sample from the intermediate zone was crushed to obtain - 100 to + 160 mesh size particles. The sample was washed to remove all dust acquired during grinding. K-feldspars were separated from plagioclase, quartz and other minerals using a "heavy liquid". The liquid was prepared by mixing bromoform with tetrachloroethane in proportions such that the density of the liquid was about 2.60. The density was checked by putting pieces of pure quartz, microcline and albite in the liquid and ascertaining that only the microcline floated whereas the quartz and albite sank to the bottom. The separation was checked under the microcsope and the process was repeated until atleast

98% pure separation of Potash feldspars was obtained.

Major elements in sixteen (16) samples and trace elements in twenty (20) samples of K-feldspars from different types of pegmatites were studied. SiO_2, Al_2O_3, K_2O, Na_2O and CaO in major elements and Co, Ni, Cr, Cu, Ge, Ga, and Pb among trace elements were determined.

METHODS USED IN ANALYSES:

Samples of K-feldspars were analysed by the rapid method of silicate analysis by Shapiro and Brannock (1962). K_2O and Na_2O were determined by Flame photo meter with solution 'B' using lithium sulphate as internal standard. CaO was determined by titration method using EDTA prepared by disodium salt. SiO_2 and Al_2O_3 were determined by spectrophotometer in an aliquot of solution 'A' by developing coloured ions of respective elements and measuring their absorbance on the selected wavelengths. For the determination of SiO_2 and Al_2O_3, Ammonium molybdate, Tartaric acid, Hydroxylaminehydrochloride, Potassium ferricyanide, Sodium acetate, Alizarin red and reducing solutions were used.

For eliminating error due to possible 'Reagent contamination, a reagent blank was prepared with distilled water for each set of determinations (detailed techniques and methods used in different analyses are given in Appendix A).

The result of the analyses of major oxides is given in Table I. It is evident from the table that K_2O, Na_2O and CaO concentrations in various types of pegmatites are not significantly different. K_2O ranges from 13.25 to 15.5 in K-feldspars of beryl and Columbite-tentalite bearing pegmatites, 11.00 to 13.00 in muscovite bearing pegmatites and 12.5 to 13.00 in barren pegmatites. Na_2O content ranges from 1.15 to 1.8 in beryl and columbite-tentalite bearing pegmatite and uranium minerals bearing pegmatites, 1.90 to 2.30 in muscovite bearing pegmatites and 1.65 to 1.80 in barren pegmatites. CaO content in beryl and columbite-tentalite pegmatites ranges from 0.87 to 2.24, 0.65 to 1.01 in muscovite bearing pegmatite, and 1.07 to 1.49 in barren pegmatites.

Figure 6 shows the plots of % K_2O versus % Na_2O in K-feldspars of the different types of pegmatites. It is observed that samples from different types of pegmatites plot in distinct zones. In the same way, CaO versus K_2O plots (Figure 7), form distinct zones for various types of pegmatites.

Feldspar composition is a qualitative indication of the thermal history of the rock and may be used to compare different types of pegmatites. Heier (1962), Barth (1951, 1962, 1969) have suggested that higher temperature of

TABLE I

MAJOR OXIDE COMPOSITION OF POTASH-FELDSPARS OF VARIOUS TYPES OF PEGMATITE

S.No.	Sample No.	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Na_2O + CaO
1	2C/B	65.068	18.40	14.75	1.20	1.01	2.21
2	4B/B C	64.368	18.744	13.25	1.30	1.29	2.59
3	8C/B C	63.661	18.469	14.50	1.15	1.12	2.27
4	6C/B C	65.028	18.889	13.25	1.65	1.29	2.94
5	7C/B C	64.698	18.588	13.25	1.65	2.24	3.89
6	10B/C	63.661	18.501	13.25	1.80	1.69	3.49
7	26B/B	64.40	18.754	13.25	1.60	0.87	2.47
8	31D/U	65.143	18.830	12.75	1.40	0.85	2.25
9	13/M	66.518	17.26	13.00	2.00	0.98	2.98
10	17/M	65.812	17.364	12.50	2.20	1.01	3.21
11	20/M	64.056	19.010	12.50	1.90	0.65	2.55
12	32/M	63.853	19.046	11.50	2.00	0.67	2.67
13	2J/N	65.183	18.367	11.00	2.80	0.73	3.53
14	18B/@	65.400	18.048	12.50	1.65	1.49	3.14
15	28B/@	64.349	18.652	12.50	1.80	1.07	2.87
16	30C/@	64.071	18.644	13.00	1.65	1.40	3.05

Serial No. 1-7 are beryl, columbite tantalite bearing pegmatites.

Serial No. 9-13 are mica bearing pegmatites.

Serial No. 14-16 are barren pegmatites.

Serial No. 8 is Uranium bearing pegmatite.

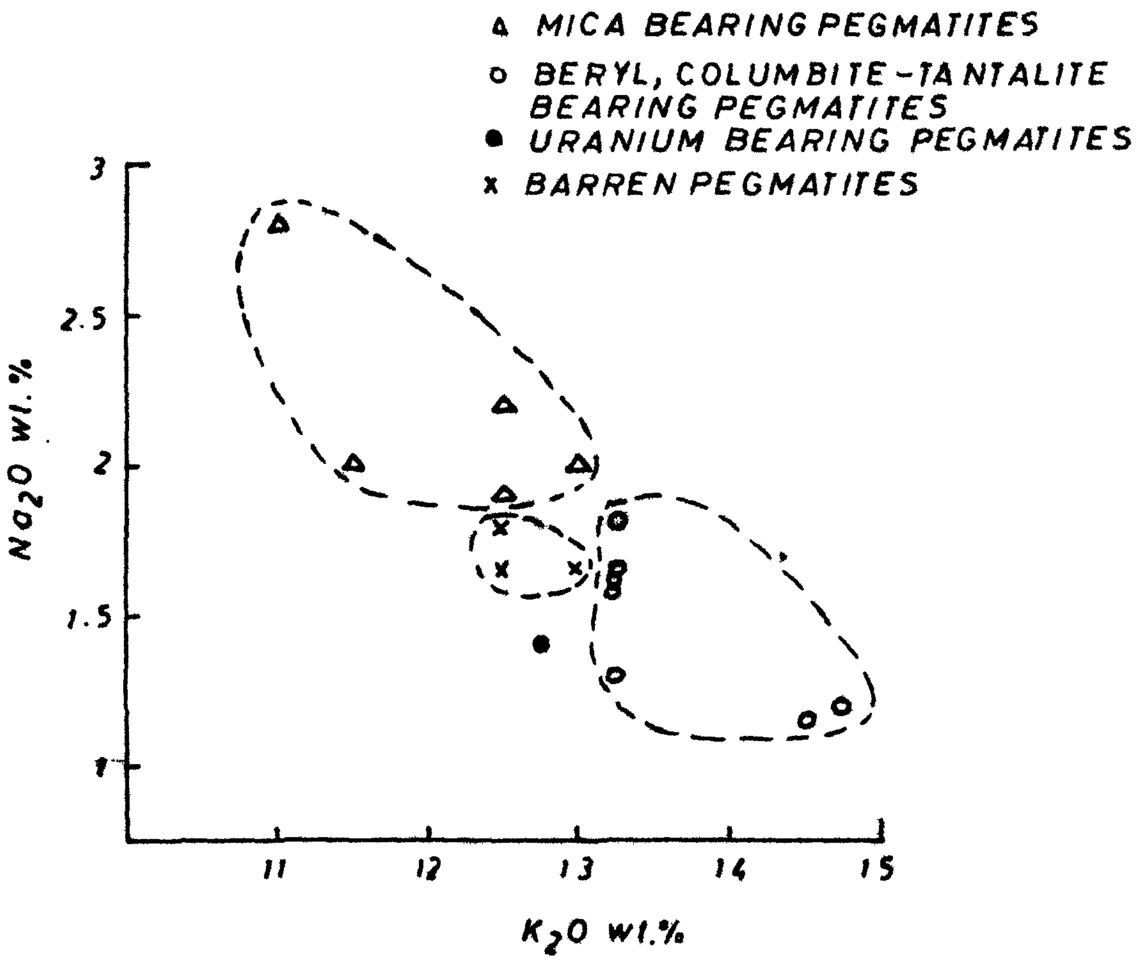

FIG. 6 K_2O : Na_2O VARIATION DIAGRAM IN K-FELDSPAR IN VARIOUS TYPES OF PEGMATITES OF DF BIHAR MICA BELT

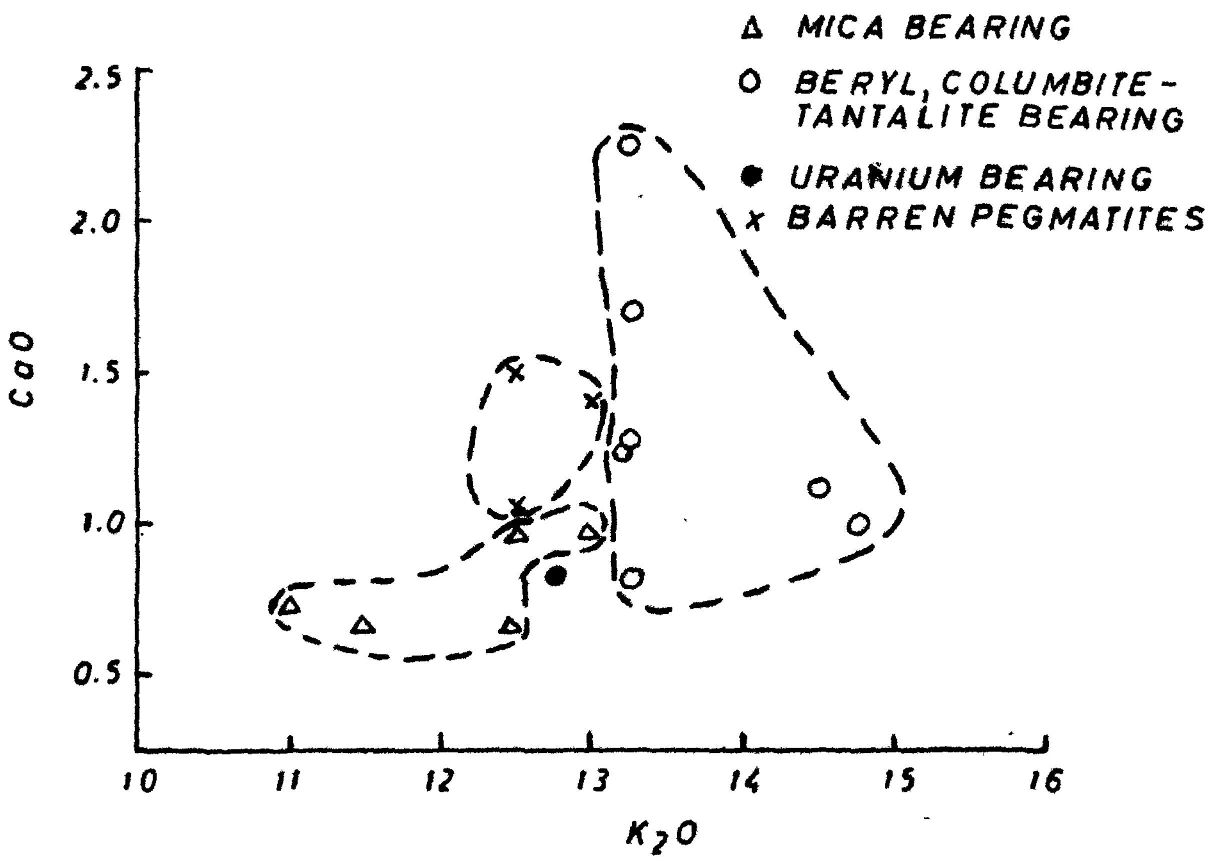

FIG. 7 PLOTS OF PER CENT K_2O Vs. CaO IN K-FELDSPAR IN PEGMATITES OF BIHAR MICA BELT

crystallisation favours the solubility of Na in Potash feldspars. Hubbard (1967) suggested that at higher crystallisation temperatures, a significant proportion of Ca may be included in alkali feldspars as solid solution. Ionic properties of K, Na, Ca elements are given in Table II.

TABLE II

SHOWING IONIC PROPERTIES OF K, Na AND Ca

Elements	Electrostatic charge	Ionic radius (Ahrens, 1952)	Ionisation potential (Ahrens, 1953)	Electronegativity
K	1	1.33	4.34	0.8
Na	1	0.97	5.14	0.9
Ca	2	0.99	11.9	1.0

Na and Ca are incorporated in the structure of K-feldspar at higher temperatures. It is observed that the average Na_2O + CaO in K-feldspars are highest in barren pegmatites (3.02), muscovite bearing pegmatites have an average of 2.98 and the least values are observed in beryl columbite-tantalite bearing pegmatites (2.83). The significantly higher values of Na_2O + CaO in Potash-feldspars of barren pegmatites indicate a higher temperature of crystallisation of such pegmatites. Muscovite bearing pegmatites probably crystallised at a slightly lower temperature than the barren pegmatites, beryl and columbite-tantalite pegmatites crystallized at the lowest temperature.

Barth (1969, p-27) has mentioned that in ternary feldspars the kinetics of exsolution reactions are complicated and not only K, Na and Ca ions are affected by Al and Si ions also have to move during the exsolution process and therefore attainment of equilibrium is seriously obstructed and phases in precipitate are influenced by the sites of nucleation and growth. Rode (1947) has suggested that at higher temperature some Al atoms might replace Si atoms of K-feldspars so that the structures could accommodate (OH)-ions to form muscovite.

Plots of percent SiO_2 versus percent Al_2O_3 for various types of pegmatites (Figure 8) do not reveal any difference in the various types of pegmatites. The plots for various types are mixed up and a separate field or zone of any particular type is not discernable.

With the crystallization of feldspars and quartz (anhydrous phases), the concentration of volatiles probably increases in the residual liquid; the volatiles have apparently been significantly responsible in the concentration and localization of economic minerals. Schaller (1925), Quirke and Kramers (1943) and Rode (1947) assumed a post-crystalline hydrothermal alteration of feldspar of pegmatites into

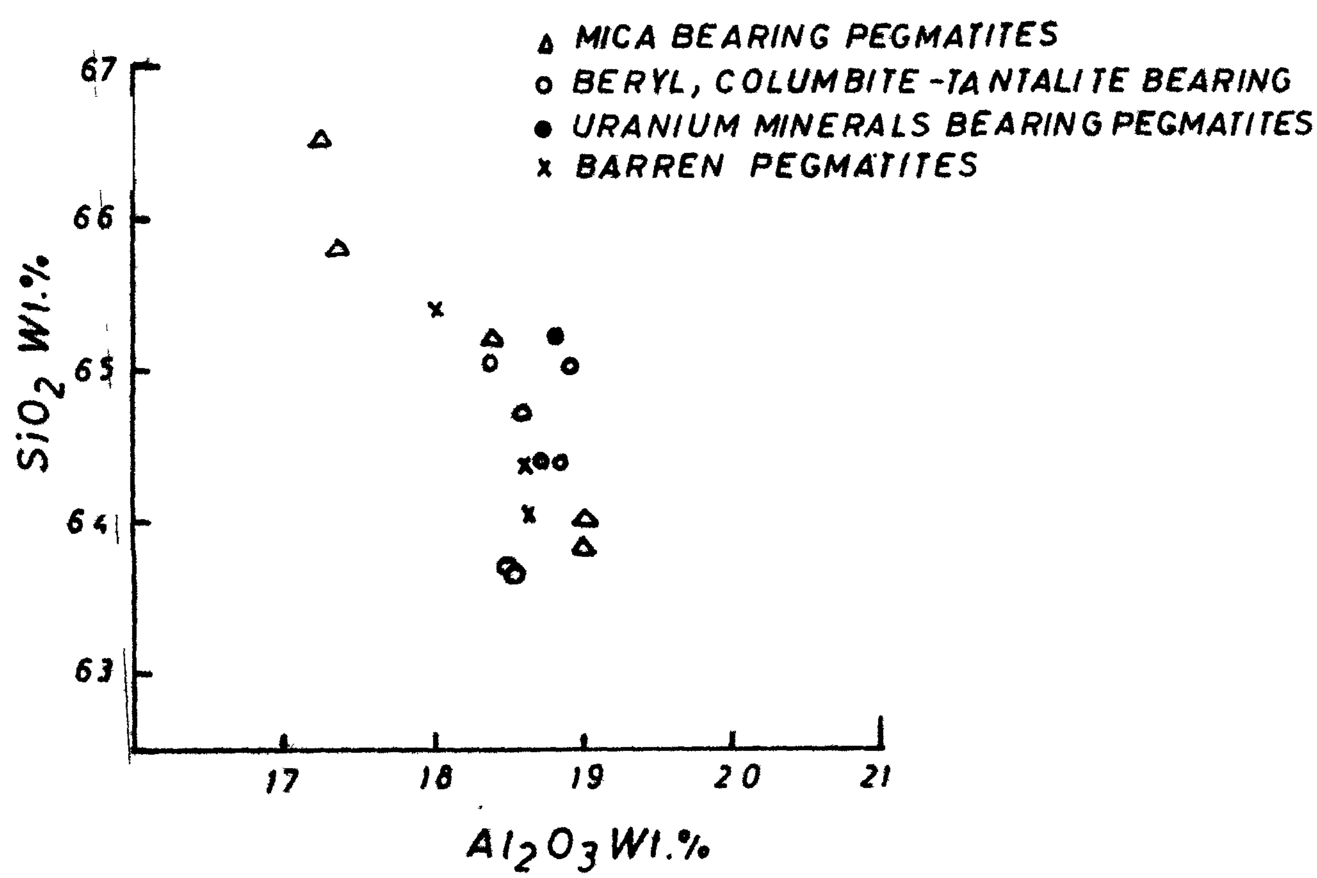

FIG. 8 PLOTS OF SiO_2 Vs. Al_2O_3 IN K-FELDSPAR IN VARIOUS TYPES OF PEGMATITES OF BIHAR MICA BELT.

muscovite at higher temperatures, facilitated by pneumato-lytic hydrothermal emanations that got attached through the cleavage planes of feldspars.

DISTRIBUTION OF TRACE ELEMENTS IN K-FELDSPAR

Twenty (20) samples of Potash feldspars were analysed to determine the concentration of trace elements which included Co, Ni, Cr, Cu, Ge, Ga, and Pb.

Trace elements in Potash feldspars were analysed by D-C Arch Emission spectrograph using the methods suggested by Ahrens and Taylor (1961). (Detailed methods and techniques are given in Appendix A). The result of the analyses is given in table III.

It is evident from Table III that there is not much difference in the trace elements concentrations in the K-feldspars of various types of pegmatites. Co is mostly below detection line whereas Ni varies from 1 ppm to 10 ppm, Ga and Pb are below 10 ppm in all the samples.

Cu^+ similar in size to Na^+, the Cu-O bond is much more covalent than Na-O bond as is clear from both electronegativity and ionisation potential values (Taylor, 1965). Cu^+ may enter into feldspars substituting Na^+ and Ca^+ and may be expected in most of the rock forming minerals (Ringwood, 1955 a). According to Taylor (1965), Cu/Na ratio may be a

TABLE III

TRACE ELEMENTS CONCENTRATION IN POTASH-FELDSPARS OF VARIOUS TYPES OF PEGMATITES

Serial No.	Sample No.	Co	Ni	Cr	Cu	Ge	Ga	Pb
1	2C/B	4	2	4	<1	40	<10	<10
2	4C/B C	N.D	1	6	2	N.D	16	<10
3	5C/B C	N.D	4	6	N.D	25	<10	<10
4	6C/B C	N.D	3	5	<1	41	<10	<10
5	7C/B C	N.D	N.D	N.D	N.D	N.D	<10	<10
6	10B/C	N.D	1	N.D.	<1	N.D	<10	<10
7	26B/B	N.D	<1	10	<1	N.D.	11	<10
8	45B/L	N.D	2	6	<1	N.D.	<10	<10
9	31D/U	N.D	8	19	1	N.D	12	<10
10	13B/M	N.D	2	8	<1	N.D	<10	<10
11	17B/M	N.D	5	18	N.D	N.D	<10	<10
12	20B/M	N.D	1	12	1	N.D	13	<10
13	32C/N	N.D	2	4	<1	N.D	N.D	<10
14	102J/M	<1	7	19	<1	44	<10	<10
15	16B/M	N.D	2	13	<1	N.D	N.D	<10
16	34B/M	<1	1	<1	<1	41	<10	<10
17	18B/O	N.D	3	9	1	N.D	N.D	<10
18	28B/O	N.D	10	N.D	1	N.D	N.D	<10
19	30B/O	N.D	2	13	1	N.D	11	<10
20	145C/O	N.D	1	10	N.D	N.D	N.D	<10

Serial No. 1-7 are beryl, columbite-tantalite bearing pegmatites.
Serial No. 8-9 are lithium and uranium minerals bearing pegmatites.
Serial No. 10-16 are mica bearing pegmatites.
Serial No. 17-20 are barren pegmatites respectively.

useful index of the degree of fractionation, it should increase during fractionation. However, the Cu/Na ratios do not show any significant variation in the various types of pegmatites. However, plots of Cu versus Na show different fields for various types of pegmatites (Fig. 9).

STRUCTURAL STATE OF K-FELDSPARS

Structural state of K-feldspars was determined to compare the thermal histories of various types of pegmatites. The distribution of Al and Si in tetrahedral sites of feldspars is controlled by the rate of cooling of the rock; duration of time that the feldspars remained near the transformation temperature may have great effect on Al:Si arrangements (Wright, 1967). In all low feldspars, those which have crystallized at slow rate of cooling, an idealised ordered arrangement is met, whereas in high feldspars with fast rate of cooling, a disordered arrangement is seen (McGaw, 1959).

The temperature of triclinic-monoclinic transition of K-feldspars has been determined by many workers. Goldsmith and Laves (1954 a) found that microcline could be hydrothermally altered to orthoclase at 525°. Barth (1959) concludes that the transition in K-feldspars occur over a range of temperature, from 300° to 500°C. Mackenzie and Smith (1961) proposed a range of approximately 250°C to 300°C. Tomisaka (1962) found that at high water pressure

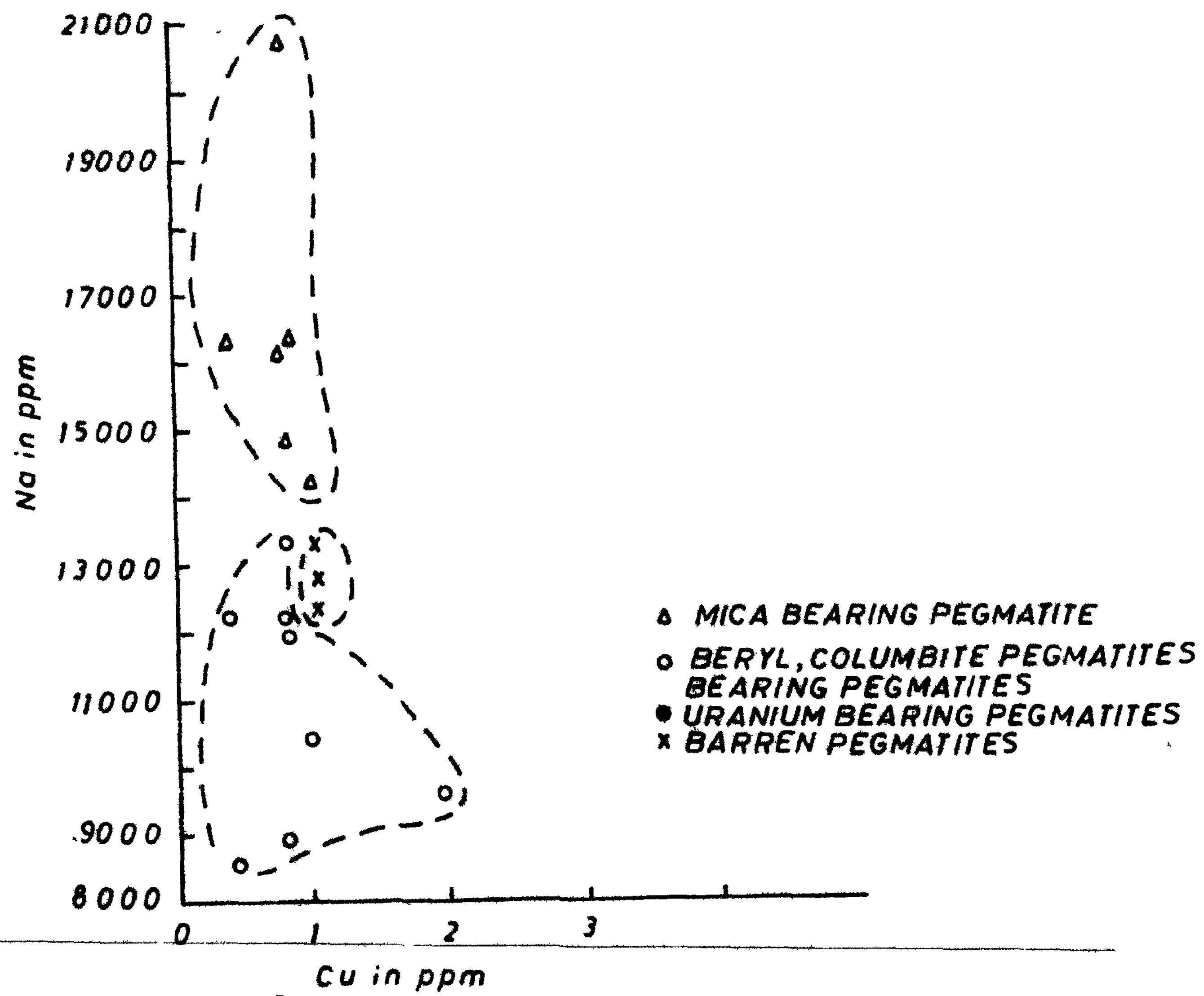

FIG. 9 PLOTS OF Cu Vs. Na in K FELDSPAR IN VARIOUS TYPES OF PEGMATITES OF BIHAR MICA BELT

Orthoclase-microcline transition takes place at temperatures between 360° to 470°C. Hart (1964) and Steiger and Hart (1967) studied the contact aureole of Eldorado stock in the Pre-cambrian rocks (Gneisses, Schists, and Amphibolites) in Colorado. Approaching the contact, they found an abrupt change from highly triclinic microcline to monoclinic orthoclase and concluded that the change probably took place at a temperature of less than 400°C. Wright (1967) studied the pegmatites within the same contact zone, and attributed the transformation of triclinic microcline to monoclinic orthoclase to contact metamorphism. He concluded that the upper stability limit of maximum microcline is at 375 ± 50°C. Barth (1969) has suggested that the transition Triclinic-Monocline is around 400°C.

Structural state of the feldspars was determined by the measure of triclinicity ($\triangle$). With increase in Al/Si disorder in alkali feldspar, the spacing of $h\,k\,l$ and $h\,\bar{k}\,l$ approach each other and ultimately unite as single reflection. Goldsmith and Laves (1954) proposed a formula for the determination of triclinicity ($\triangle$) which is as follows:

$$\triangle = 12.5\,(d_{131} - d_{1\bar{3}1})$$

If $\triangle = 1$, fully ordered (maximum microcline) i.e. maximum possible triclinicity; $\triangle = 0$, fully disordered; the alkali feldspar is monoclinic.

Eighteen (18) samples of Potash feldspars representing beryl bearing, columbite-tantalite bearing, muscovite bearing, lithium and radioactive minerals bearing pegmatites and barren pegmatites were studied.

Finely ground K-feldspars were run on an X-ray Diffractometer at a goniometer scanning speed of 1/4°2θ per minute. The chart speed was set so that 1°2θ = 1 innch. Diffractogram was made from 29° to 31° (Goldsmith and Laves, 1954). Detailed method is given in Appendix B.

Triclinicity values observed for various types of pegmatites are shown in Table IV.

TABLE IV

RANGE OF TRICLINICITY VALUES OF K-FELDSPARS IN VARIOUS TYPES OF PEGMATITES

Type of pegmatites	Range of $\triangle$ value
1. Barren pegmatites (3)	0.9625-0.9875
2. Muscovite bearing pegmatites (5)	0.8875-0.9375
3. Beryl columbite-tentalite bearing pegmatites (7)	0.8875-0.9875
4. Lithium and Uranium minerals bearing pegmatites (3)	0.9125-0.9625

The figures given in brackets are the number of samples studied for each type.

It is evident from Table IV that there is no significant difference in the triclinicity (Δ) values of the different types of pegmatite. The triclinicity values and structural state of different types of pegmatite indicate that all the K-feldspars are maximum microcline. This highly ordered structural state of Potash feldspars in all types of pegmatites suggests a very slow rate of cooling with the crystallization temperature below 400°C.

CHAPTER V

SUMMARY AND CONCLUSION

The pegmatites of Bihar Mica Belt are very important because of the occurrence of certain economic minerals some of them are of strategic importance. The pegmatites of the belt produce lot of good quality ruby mica and fulfil the needs and requirements of the country as well as of the whole world. Beryl, Columbite-tentalite and lithium minerals are being exported to various countries, they fetch considerable foreign exchange.

The method for prospecting for Mica and other economic minerals in pegmatites till today is unscientific. It is usually done by surface scratching, locally known as "Upperchella" working; the pegmatites which are exposed to the surface and show indications of economic minerals are dug up. In this way the prospectors or miners spend lot of money on random digging and trenching in the pegmatites in search of various economic minerals. This is due to the lack of knowledge of any guide or criteria which can be helpful in locating the deposits of economic minerals in pegmatites.

Earlier workers have discussed the mode of emplacement, the deformational features and the origin of pegmatites of Bihar Mica Belt. Geochemical studies on the pegmatites of Bihar Mica Belt have not been carried out in detail.

The present study was conducted to evolve a criteria which can be used as guide for locating pegmatites which contain economic minerals such as muscovite, beryl, columbite-tentalite, lithium and uranium minerals. The pegmatites were classified on the basis of the occurrence of economic minerals in them (mined presently or reported to have produced in past) into muscovite bearing, beryl bearing, columbite-tentalite bearing, lithium and uranium minerals bearing pegmatites and barren pegmatites (which lack in any economic mineral in profitably exploitable amount). A comparative study of various types of pegmatites was expected to reveal the difference in the major and trace elements concentrations which may be used as a criteria to decipher such pegmatites. Samples from various types of pegmatites were collected. Since the pegmatites have an extremely large grain size and representative sample of the whole body cannot be easily obtained, individual minerals of the different types of pegmatites were collected. In the present study K-feldspars were analysed. It was separated from quartz and plagioclases by "heavy liquid" method.

The major elements of sixteen (16) samples and trace elements in twenty (20) samples of Potash-feldspars were analysed. SiO_2, Al_2O_3, K_2O, Na_2O and CaO among major elements and in trace elements, Co, Ni, Cr, Cu, Ge, Ga and Pb were determined. Rb, Cs, Ba, Sr, etc. could not be analyzed because of the lack of facilities.

On plotting K_2O versus Na_2O, K_2O versus CaO, the different types of pegmatites plot in different fields. Average values of Na_2O + CaO in K-feldspars are highest in barren pegmatites, slightly less in muscovite bearing pegmatites and least in beryl, columbite tentalite and uranium minerals bearing pegmatites.

To compare the thermal histories of various types of pegmatites, and the role of volatiles, the triclinicity ($\triangle$) of K-feldspars was determined.

The triclinicity values for different types of pegmatites suggest that all the K-feldspars studied are maximum microclines, which suggest that all the pegmatites crystallized at temperatures lower than 400°C, the volatile content was high. There is no significent difference in triclinicity ($\triangle$) values in K-feldspars of various types of pegmatites. As such, this may not be used as a criterion to decipher the different types of pegmatites.

Since Na and Ca are incorporated into structures of K-feldspars at higher temperatures, concentration of these elements in K-feldspars may be related to the temperature of crystallization of pegmatites. It may be concluded that the pegmatites crystallised at relatively higher temperatures are generally barren, whereas those pegmatites which crystallised at lower temperatures may be expected to contain beryl, columbite-tentalite and uranium minerals; muscovite bearing pegmatites fall somewhere between the two.

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APPENDIX - A

TECHNIQUES AND METHODS USED FOR ANALYSES

MAJOR ELEMENTS ANALYSES:

Rapid Silicate Analyses methods of Shapiro and Brannock (1962) were employed for the major elements analyses of K-feldspars.

SiO_2 and Al_2O_3 were determined by Spectrophotometer by developing coloured ions of respective elements and measuring their absorbance on the following selected wave lengths.

SiO_2 - 640 mu - Red sensitivity
Al_2O_3 - 475 mu - Blue sensitivity

For eliminating error due to possible "reagent contamination", a reagent blank was prepared with distilled water for each set of determination.

SiO_2 and Al_2O_3 were determined in an aliquot of solution 'A', prepared by fusion and digestion of a known weight (00.1 gm) of sample with sixteen pellets of sodium hydroxide (NaOH) in a Nickel crucible. After cooling, the melts are leached with water and solution are acidified with 20 cc. of 1:1 HCl, and boiled for ten minutes on a hot plate, then the solutions are taken into a litre volume.

K_2O and Na_2O were determined from an aliquot of the solution 'B', prepared by digesting a known weight (0.5 gm) of sample in platinum crucible with concentrated HF Acid

(25-30 ml) and one or two drops of H_2SO_4 over a steam bath for about 4-6 hours. When the sample was completely dried, 10 cc. of dilute HNO_3 was added to it, and washed thoroughly with the crucible and boiled for 15 minutes. After cooling of solution it was made to 250 ml. The solution was run on a Flame photometer for the determination of the concentrations.

CaO, was also determined from the separate aliquote of the above solution by titration against EDTA, on an automatic titration unit.

STANDARDS USED IN THE PRESENT WORK

As, there are no natural standards for Potash feldspars, only synthetic standards were used.

For the determination of Na_2O and K_2O, a series of standards containing 0.3, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 5.0, 6.0, and 5.0, 6.0, 8.0, 10.0, 15.0, 16.0% pure NaCl and KCl respectively were prepared and stored in plastic bottles. Lithium sulphate was used as Internal Standard for both Na_2O and K_2O.

For the determination of SiO_2 and Al_2O_3, Ammonium molybdate, Tartaric acid, Reducing solutions and Hydroxylamine hydrochloride, Potassium ferricyanide sodium acetate and Alizarin red, were used.

CaO was determined with the help of EDTA prepared by weighing 3.7225 gm of disodium salt in one litre of distilled water.

Before using any chemical for the preparation of these standards, its blank was predetermined and necessary correction factor was found out.

TRACE ELEMENTS

Samples of Potash feldspars were analysed on D-C, Arc Emission Spectrograph for their trace elements concentrations.

The spectrochemical method is governed by the principle that as atoms of different elements have different electronic configurations (structures), each element shows a distinct and characteristic spectrum, which serves as a conclusive positive qualitative test, when it is excited by a suitable excitation source to emit radiant energy. In quantitative analysis the brightness of a spectrum is used as a measure of concentration.

Sources of excitation are of three types; Flame, Arc (D-C or high voltage A-C Arc), and Spark. Among these the D-C arc excitation source is the most inexpensive, simple and easily operated. It is readily adapted to the analyses of almost all inorganic substances, including rocks and minerals. Generally D-C arc, records an accuracy within 2.5% to 10% of correct amount.

STANDARDS USED IN TRACE ELEMENT ANALYSES

For highest accuracy in D-C arc emission spectrographic study of elements, an internal standard was necessary. Graphites with Indium and Palladium was used as an Internal Standard. After its thoroughly mixing for about 20 hours it was mixed with the Potash feldspar sample in the ratio of 1 : 3.

APPENDIX - B

X-RAY METHOD FOR DETERMINATION OF TRICLINICITY OF K-FELDSPAR

Smear mounts were made of finely ground Potash-feldspar. The mounts were run on an X-ray diffractometer at a goniometer speed of $1/4°2\theta$ per minute. The chart speed was set so that $1°2\theta$ = 1 inch. Peak positions were measured at the estimated center line of approximately top 1/10 of each peak (Orville, 1967). Duplicate diffractions was run from higher to lower 2θ (opposite of the first run) and an average of the two 2θ values was recorded. If the difference in the two values exceeded 0.04°, a third run was taken. Measurements of 2θ values for the two reflections (131), ($1\bar{3}1$) were recorded.